NsG-130

UNPUBLISHED PRELIMINARY DATA

Specular Reflection of Phonons in Superfluid Helium at 0.33°K

J. Fajans* and C. Z. Rosen
Stevens Institute of Technology
Hoboken, New Jersey

Specular reflection of phonons is observed in superfluid helium at 0.33°K. The phonons are generated at a small carbon transmitter and travel along various directions in the experimental chamber without colliding with other phonons.[1] Some phonons go directly to a concave fused quartz mirror shown in Fig. 1, where they are specularly reflected; and, when the mirror is sharply focussed[2] so that the carbon receiver is conjugate to the carbon transmitter, an enhanced signal 14 times greater than the unfocussed phonon background signal is recorded. Thus, phonons are directly "manipulated" simply by means of a spherical mirror to form the heater image at the carbon detector.

The carbon transmitter and receiver are two opposite 90° arcs of Dag 154 carbon. Each arc has an inner radius of 0.050 inches and an outer radius of 0.065 inches. They are about 0.002 inches thick, 0.015 inches wide and 1.4×10^{-3} square inches in area. One expects that the phonon beam has a cross section similar in shape and close in size to the transmitter. Since the focussed signal is as much as 14 times larger than the phonon background; it would appear that most of the phonons proceed from the heater in the forward direction keeping the width of the phonon beam close to or smaller than the dimensions of the electrode. The narrowness of the focussing (about 12 minutes of arc) indicates that the beam is probably smaller

* Presently on leave at the University of Kabul, Afghanistan

in cross-section than the electrode. Fig. 2 is one of the seven observations made of phonon signal strength vs. mirror angle.

There have been experiments conducted by Whitworth[3] and Fairbank and Wilks[4] whose results have been explained in terms of specular reflection of phonons. In these experiments, however, the reflection was that of phonons from the walls of the containing vessel. In Whitworth's paper specular reflection was deduced from observed values of the thermal conductivity of liquid helium below 0.6°K. In the present experiment the specular reflection from the walls serves only to contribute to the background signal.

A model 50-A Min A tron impulse generator is used to produce two signals, one at 155 cps and the other at 310.4 cps. The lower frequency is filtered of all harmonics and sent into the carbon transmitter where it generates 310 cps local Joule heating of the liquid helium. The wavelength of the second sound arising from the Joule heat is 48 cm. Since this wavelength is much greater than the dimensions of the experimental chamber, it is clear that the observed enhancement of the received 310 cps signal could not be due to the specular reflection of thermal waves. After the received 310 cps signal is amplified it is mixed with the higher 310.4 cps signal and a rectified signal of 0.4 cps is displayed on a strip chart recorder. The 0.33°K temperature was attained by means of He^3 refrigerating system.[5]

The ability to focus and diffract phonons would make available a powerful new method for studying phonon spectra of solids.[6] The construction of a very high frequency (10^{10} - 10^{11} cps) phonon "monochromator", i.e., source of mono-energetic phonons analogous to optical monochromators, would become feasible.

Phonon spectroscopy of solids would make it possible to study phonon-phonon, phonon-photon, phonon-electron, and phonon-imperfection interactions which play important roles in electrical and heat conduction, X-ray and neutron scattering, and other solid state phenomena.

ACKNOWLEDGMENTS

The study was supported by the Air Force Office of Scientific Research Contract #AF 49(638)-352 and by the National Aeronautics and Space Administration Grant #NsG-130-61.

Footnotes

1. L. D. Landau and I. M. Khalatnikov, J. Exp. Theor. Physics, U.S.S.R. 19 637, 709 (1949).

   I. M. Khalatnikov, J. Exp. Theor. Physics, U.S.S.R. 20 243 (1950).

   On the basis of Landau-Khalatnikov theory, the longitudinal mean free path is greater than 50 cm at 0.33°K; furthermore, at this low temperature only longitudinal phonons propagate in liquid He II. Experimentally, according to Kramer's et al Physica 20 743 (1954), the mean free path at 0.33°K is 6.4 cm which is still greater than the dimensions of the apparatus.

2. An electromagnet set outside the cryostat moves the mirror.

3. R. W. Whitworth (LT5), 33.

4. H. A. Fairbank and J. Wilks, Proc. Roy. Soc. A231, 545 (1955).

5. R. S. I., H. A. Reich, and R. L. Garwin, 30, No. 1.

6. J. Phys. Chem. Solids, E. T. Kornhauser, 21, 228 (1961).

Fig. 1. Geometry of Fused Quartz Mirror and Carbon Electrodes

abc is a possible path traveled by a longitudinal phonon from transmitter to mirror to receiver.

The fused quartz mirror has a 1/2 inch radius of curvature.

The inside diameter of the brass cylinder is 13/16 inches.

All dimensions given here are in inches.

Fig. 2. Signal Strength vs. Angle

Recorder Rate = 0.917 inches per minute

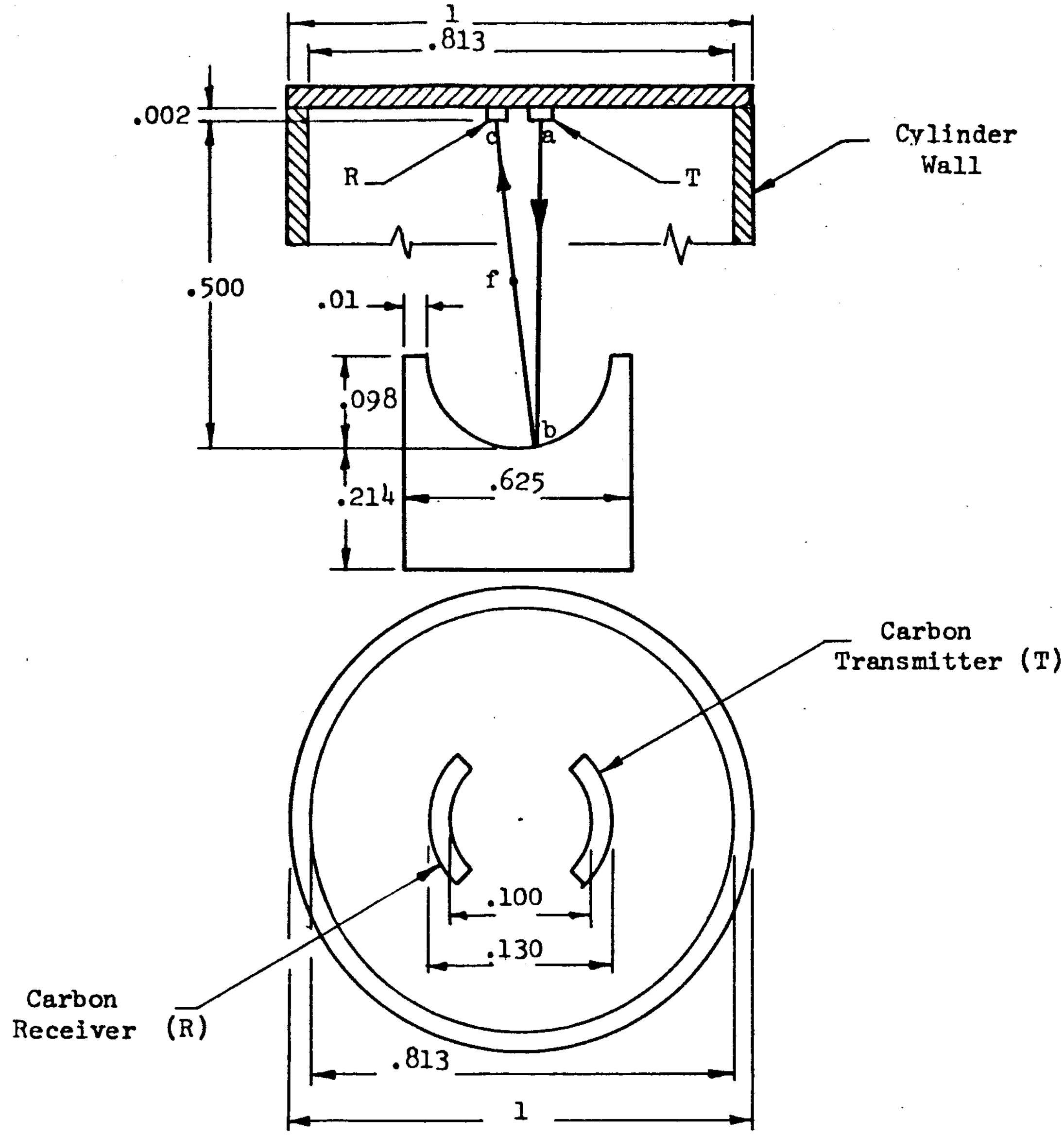
1
.813
.002
Cylinder
Wall
c
a
R
T
f
.500
.01
.098
b
.214
.625
Carbon
Transmitter (T)
.100
.130
Carbon
Receiver (R)
.813
1

FIG. 1.

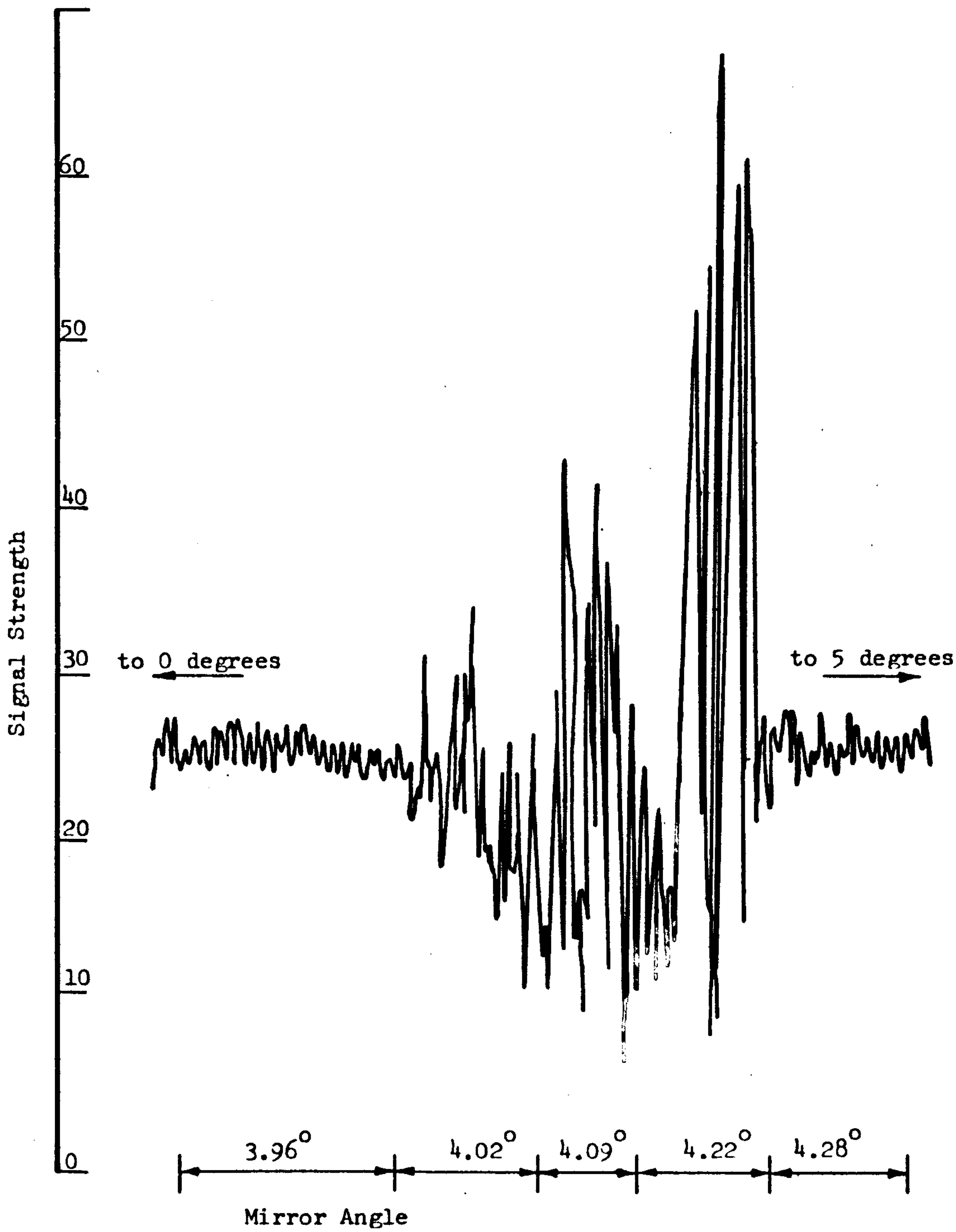
Signal Strength
60
50
40
30
20
10
0
to 0 degrees
to 5 degrees
3.96°
4.02°
4.09°
4.22°
4.28°
Mirror Angle

FIG. 2.